MAR X 0 1982

1051-H-11

Y3. N88:25/2333/v.5

COMPLETED

NUREG/CR-2333
BNL-NUREG-51458
Vol. 5

Nuclear Waste Management Technical Support in the Development of Nuclear Waste Form Criteria for the NRC

ORIGINAL

Task 5
National Waste Package Program

Prepared by M. S. Davis

Brookhaven National Laboratory

Prepared for
U.S. Nuclear Regulatory
Commission

I

NOTICE

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, or any of their employees, makes any warranty, expressed or implied, or assumes any legal liability or responsibility for any third party's use, or the results of such use, of any information, apparatus, product or process disclosed in this report, or represents that its use by such third party would not infringe privately owned rights.

The views expressed in this report are not necessarily those of the U.S. Nuclear Regulatory Commission.

Availability of Reference Materials Cited in NRC Publications

Most documents cited in NRC publications will be available from one of the following sources:

1. The NRC Public Document Room, 1717 H Street, N.W.
   Washington, DC 20555
2. The NRC/GPO Sales Program, U.S. Nuclear Regulatory Commission,
   Washington, DC 20555
3. The National Technical Information Service, Springfield, VA 22161

Although the listing that follows represents the majority of documents cited in NRC publications, it is not intended to be exhaustive.

Referenced documents available for inspection and copying for a fee from the NRC Public Document Room include NRC correspondence and internal NRC memoranda; NRC Office of Inspection and Enforcement bulletins, circulars, information notices, inspection and investigation notices; Licensee Event Reports; vendor reports and correspondence; Commission papers; and applicant and licensee documents and correspondence.

The following documents in the NUREG series are available for purchase from the NRC/GPO Sales Program: formal NRC staff and contractor reports, NRC-sponsored conference proceedings, and NRC booklets and brochures. Also available are Regulatory Guides, NRC regulations in the *Code of Federal Regulations*, and *Nuclear Regulatory Commission Issuances*.

Documents available from the National Technical Information Service include NUREG series reports and technical reports prepared by other federal agencies and reports prepared by the Atomic Energy Commission, forerunner agency to the Nuclear Regulatory Commission.

Documents available from public and special technical libraries include all open literature items, such as books, journal and periodical articles, and transactions. *Federal Register* notices, federal and state legislation, and congressional reports can usually be obtained from these libraries.

Documents such as theses, dissertations, foreign reports and translations, and non-NRC conference proceedings are available for purchase from the organization sponsoring the publication cited.

Single copies of NRC draft reports are available free upon written request to the Division of Technical Information and Document Control, U.S. Nuclear Regulatory Commission, Washington, DC 20555.

Copies of industry codes and standards used in a substantive manner in the NRC regulatory process are maintained at the NRC Library, 7920 Norfolk Avenue, Bethesda, Maryland, and are available there for reference use by the public. Codes and standards are usually copyrighted and may be purchased from the originating organization or, if they are American National Standards, from the American National Standards Institute, 1430 Broadway, New York, NY 10018.

GPO Printed copy price: $4.25

NUREG/CR-2333
BNL-NUREG-51458
Vol. 5

Nuclear Waste Management Technical Support in the Development of Nuclear Waste Form Criteria for the NRC

Task 5
National Waste Package Program

Manuscript Completed: August 1981
Date Published: February 1982

Prepared by
M. S. Davis

Department of Nuclear Energy
Brookhaven National Laboratory
Upton, NY 11973

Prepared for
Division of Waste Management
Office of Nuclear Material Safety and Safeguards
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555
NRC FIN A3158

III

IMPORTANT NOTICE

All references made to the BNL interim reports, "NRC Nuclear Waste Management Technical Support in the Development of Nuclear Waste Form Criteria," Tasks 1-5, should be disregarded. The following references should be inserted in their places, as applicable.

R. Dayal, et al., "Nuclear Waste Management Technical Support in the Development of Nuclear Waste Form Criteria for the NRC, Task 1: Waste Package Overview," NUREG/CR-2333, Vol. 1, BNL-NUREG-51458, February 1982.

G. Bida, et al., "Nuclear Waste Management Technical Support in the Development of Nuclear Waste Form Criteria for the NRC, Task 2: Alternative TRU Technologies," NUREG/CR-2333, Vol. 2, BNL-NUREG-51458, February 1982.

D. Majumdar, et al., "Nuclear Waste Management Technical Support in the Development of Nuclear Waste Form Criteria for the NRC, Task 3: Waste Inventory Review," NUREG/CR-2333, Vol. 3, BNL-NUREG-51458, February 1982.

T.M. Ahn, et al., "Nuclear Waste Management Technical Support in the Development of Nuclear Waste Form Criteria for the NRC, Task 4: Test Development Review," NUREG/CR-2333, Vol. 4, BNL-NUREG-51458, February 1982.

M.S. Davis, "Nuclear Waste Management Technical Support in the Development of Nuclear Waste Form Criteria for the NRC, Task 5: National Waste Package Program," NUREG/CR-2333, Vol. 5, BNL-NUREG-51458, February 1982.

ABSTRACT

This report assesses the need for a centrally organized waste package effort and whether the present program meets those needs. It is the conclusion of the BNL staff that while the DOE has in principle organized a national effort to develop high-integrity waste packages for geologic disposal of high level waste, the DOE effort has not yet produced data indicating that a waste package will comply with NRC's criteria. The BNL staff feels, however, that such a package is achievable either by development of high integrity components which by themselves could comply with 1,000-year containment or by the development of new waste package designs that could comply with the containment and the controlled release criteria in the 10 CFR 60 performance objectives.

CONTENTS

ABSTRACT iii
ACKNOWLEDGEMENTS vi
EXECUTIVE SUMMARY. vii

1. INTRODUCTION 1

2. EFFECTIVENESS OF THE DOE WASTE PACKAGE PROGRAM 3
   2.1 Waste Package Performance Objectives 3
   2.2 Waste Forms 5
      2.2.1 High Level Waste Forms 5
      2.2.2 TRU Waste Forms 6
   2.3 Containers 8
   2.4 Backfills 9
   2.5 Whole Package Testing 10
   2.6 Modeling of Package Performance 11

3. RECOMMENDATIONS ON SAMPLE (TICODE-12-BOROSILICATE GLASS) WASTE PACKAGE 12
   3.1 Performance of Borosilicate Glass 12
   3.2 Container 13

4. SPECIFIC NRC INFORMATIONAL NEEDS ON SAMPLE WASTE PACKAGE COMPONENTS 16

5. SUMMARY/CONCLUSIONS 22

6. REFERENCES 23

APPENDIX 1 - NWTS PROGRAM EVALUATION 24

ACKNOWLEDGMENTS

The author gratefully acknowledges the contributions made by the Brookhaven National Laboratory High Level Waste Technical Assistance staff:

T. M. Ahn
G. Bida
K. S. Czyscinski
R. Dayal
E. M. Franz
B. S. Lee
N. S. McIntyre
D. R. MacKenzie
P. Soo
K. J. Swyler
E. Veakis
R. Wilke

EXECUTIVE SUMMARY

This report assesses the need for a centrally organized waste package effort and whether the present national program meets those needs. It is the conclusion of the BNL staff that while the DOE has in principle organized a national effort to develop high-integrity waste packages for geologic disposal of high level waste, the effort has not yet produced data to demonstrate that a waste package will comply with NRC's criteria. The BNL staff feels, however, that such a package is achievable either by development of high integrity components which by themselves could comply with 1,000-year containment or by the development of new waste package designs that could comply with both the containment and the controlled release criteria in the 10CFR 60 performance objectives.

Most DOE programs are single component oriented, thus our assessment deals mainly with single component properties and performance. However, the performance objectives are on the waste package and underground facility, in multicomponent systems. While we do not now see that DOE has developed the data to qualify any one component for one or all of the performance criteria, it is the BNL staff's opinion that a system could in fact be developed to satisfy NRC's proposed criteria.

In terms of waste forms, we feel that high-integrity components such as pyrolytic carbon coated waste and radioactive glass coated with non-radioactive glass offer higher potential than normal borosilicate waste glass.

The existing container reasearch program has yet to produce the data base on which to assess the potential of a container material to contain the waste for 1,000 years. However, there may be the potential, based on Swedish calculations and work done on titanium in the DOE program, that Ti or its alloys may satisfy this criterion.

Our reviews and evaluations of DOE backfill work have been limited because backfill was not always considered part of the waste package. Nevertheless, the BNL staff still supports its past conviction that existing data on natural backfills indicate that water flow properties through them are not predictable. Uncertainties exist because of irreversible swelling and shrinkage properties resulting from sequences of wetting and drying. Consequently, we do not feel that existing data on natural backfills will be acceptable as the sole source for satisfying containment and the long-term release rate criteria. We have, however, evaluated a synthetic zeolite system which we believe is an example of a backfill with a potential to satisfy both criteria. In this particular case, it is the BNL staff's opinion that existing technology and data for this system indicate that major development programs may not be required to qualify this material for licensing applications. We feel that presently the most likely means available for satisfying 10 CFR 60 with a single package component is through the performance of a discrete backfill.

1. INTRODUCTION

BNL is required to assess the need for a centrally organized waste package effort and determine whether the present or planned program meets these needs. The approach taken in this report is that, based on existing national policy, an existing regulatory policy, and a consensus view of the scientific community, there is a need for a centrally organized waste package effort.

The present national policy for the management of high level waste was established by President Carter[1] and calls for the disposal in "mined geologic repositories capable of accepting waste from both reprocessing and unreprocessed commercial spent fuel." The Carter policy was based on recommendations made by the Interagency Review Group (IRG) on Radioactive Waste Management.[2] The IRG committee stressed the importance of proceeding in a technically conservative stepwise manner to isolate the waste from the biosphere. The final IRG report specifically recommends the use of multiple engineered and natural barriers to ensure that the waste will be disposed of so that it poses no significant threat to public health and safety. The scope and magnitude of the problems associated with isolating the waste demand a coordinated national effort to not only characterize suitable repository sites but also to design, develop, and test those engineered barriers that will be an integral part of the overall isolation system. The IRG recognized the complexity of the management of nuclear wastes and recommended[3] "...assigning primary responsbility for planning and managing non-regulatory programs and for interfacing with regulatory programs to a single agency...," the Department of Energy (DOE). The Department fully acknowledges its responsibilities to coordinate the efforts for disposing of the waste in a technically conservative manner, including the development of "long-lived" waste packages: The DOE[4]

> ..."has the statutory mandate and lead responsibility to conduct for the Federal government research concerning nuclear waste management and ultimate disposal of certain nuclear material. Pursuant to this responsibility, the Department is conducting the National Waste Terminal Storage Program (NWTS) to develop methods to isolate such wastes and to identify appropriate sites for disposal facilities."[4]

Within the NWTS program, (Appendix 1) the Waste Package Program (WPP) has as its primary objective "...to plan and implement the technology, development, design, and production of waste packages for the isolation of nuclear wastes in deep geologic formations"[5] in the context of the overall NWTS performance objectives, general performance criteria and future (EPA,NRC) criteria.

The problems associated with designing, developing, and testing waste packages that must comply with applicable criteria, requires not only understanding what materials are needed but what the limitations of each component alone and in combination with other components are in a given environment.

It is also necessary to be able to predict with a high degree of certainty how the engineered system will behave over long periods of time in its environment, taking into consideration likely geological processes, water intrusion, etc. Despite these obstacles, the Department has adequately restated why a long-lived waste package is both necessary and desirable.[6]

> There is a viewpoint that the inherent variability of the geologic media and the limitations with which its properties and conditions can be determined, lead to the residual uncertainties in predictions of its behavior and response, using models, even if the models are accurate. This residual uncertainty may be large enough to be unacceptable, even though the repository and geology do, in fact, provide adequate isolation. The difficulty in resolving this problem may be very great.
>
> This viewpoint further proposes that the total uncertainty may be reduced by the greater degree of control which is available through development of a long-lived waste package. That is, the waste forms, containers, and backfills can embody materials whose properties are accurately known and for which geologic analogs exist and can be studied. Such a package and its performance will also contain uncertainty, but compared with the geology, the predictions may be made with more assurance.
>
> In summary, the basic incentives for a long-lived waste package are to incorporate additional conservatism into the management of high level radioactive wastes and to provide additional means for reducing overall system uncertainties of these barriers. The use of multiple barriers, with the waste package being one of these barriers, is fully consistent with the systems viewpoint adopted by the Interagency Review Group. All barriers are expected to act in concert, as a system, to assure an overall conservative performance of the entire waste repository installation.[6]

The task of developing a long-lived HLW package that will perform in a specific environment in a reasonably predictable manner over extended periods of time, therefore requires a coordinated effort on a national scale. The IRG has recommended that the national program be conducted by the DOE. The DOE has responded by establishing the NWTS program for the development of waste packages for high level nuclear waste.

The following section deals with a techincal assessment of the effectiveness of DOE's present efforts to develop a waste package that will meet proposed NRC criteria. This assessment is based on individual component properties.

2. EFFECTIVENESS OF THE DOE WASTE PACKAGE PROGRAM

2.1 Waste Package Performance Objectives

The Nuclear Regulatory Commission's (NRC) proposed rule 10 CFR 60 July 8, 1981, defines the waste package as "...the airtight, watertight, sealed container which includes the waste form and any ancillary enclosures, including shielding, discrete backfill and overpacks. The primary performance objectives placed on the waste package and the underground facility which together comprise the engineered system are:[7]

(1) Containment of wastes.* The engineered system shall be designed so that even if full or partial saturation of the underground facility were to occur, and assuming anticipated processes and events, the waste packages will contain all radionuclides for at least the first 1000 years after permanent closure. This requirement does not apply to TRU waste unless TRU waste is emplaced close enough to HLW that the TRU release rate can be significantly affected by the heat generated by the HLW."

(2) Control of releases.* For HLW, the engineered system shall be designed so that, after the first 1000 years following permanent closure, the annual release rate of any radionuclide from the engineered system into the geologic setting, assuming anticipated processes and events, is at most one part in 100,000 of the maximum amount of that radionuclide calculated to be present in the underground facility (assuming no release from the underground facility) at any time after 1000 years following permanent closure. This requirement does not apply to radionuclides whose contribution is less than 0.1% of the total annual curie release as prescribed by this paragraph.

(3) For TRU waste, the engineered system shall be designed so that following permanent closure the annual release rate of any radionuclide from the underground facility into the geologic setting, assuming anticipated processes and events, is at most one part in 100,000 of the maximum amount calculated to be present in the underground facility (assuming no release from the underground facility) at any time following permanent closure. This requirement does not apply to radionuclides whose contribution is less than 0.1% of the annual curie release as prescribed by this paragraph.

Presently there is no performance objective on the waste form, the container, the overpack, or any other single component of the waste packge. The only criterion proposed for the waste package is 1,000 year containment. The annual release

---

*The Commission specifically seeks comment on whether an ALARA principle should be applied to the performance requirements dealing with containment and control of releases. In particular, the Commission has considered whether the technical criteria should explicitly require containment to be for "as long as is reasonably achievable." Comments should address the merits of such a requirement, how to best frame it, and the practicality of its implementation.

rate criterion applies to the waste package only in so far as it might contribute to the overall performance of the underground facility. In this case, as the waste package is presently defined by the NRC, only the waste form, container, discrete backfill, or an appropriate combination, have any potential for contributing to the long-term release rate performance of the underground facility.

It is the consensus of the BNL staff that while some waste forms may have the potential to satisfy one or both of these criteria, the DOE has yet to demonstrate this. The existing container research program has yet to produce the data base on which to assess the potential of a container material to contain the waste for 1,000 years. However, there may be the potential, based on Swedish[8] calculations and work done on titanium (Ti) in the DOE program, that Ti or its alloys may satisfy this criterion. Although backfill studies have been expanded and the National Bureau of Standards has recently been contracted to study backfill materials, it is the BNL staff's opinion that the data base presently available does not lend itself to a critical evaluation in terms of the NRC's criteria. Most DOE's programs are single component oriented, thus our assessment deals mainly with single component properties and performance. However, the performance objectives are on the waste package and underground facility, in principle multicomponent systems. While we do not now see that DOE has developed the data to qualify any one component for one or all of the performance criteria, it is the staff's opinion that a system could in fact be developed to satisfy NRC's proposed criteria.

In principle the DOE has two broad options for developing a high integrity waste package. The Department could:

(a) develop high integrity components which individually meet 10 CFR 60 performance objectives,

(b) or develop good multi-component waste package designs that can pass 10 CFR 60. These packages may contain conventional engineering materials rather than ones requiring large developmental efforts.

In the first case, the DOE would have to develop the data base for single components and demonstrate at the very least that two component interactions do not significantly degrade the performance of those components the Department would select for complying with 10 CFR 60. If the DOE chooses to investigate advanced waste package designs then it must develop methods which will show that the waste package as a whole will meet the present and future NRC criteria.

A thorough review and evaluation of DOE's waste package efforts is given in BNL Tasks 1[9] and 4,[10] the most pertinent recommendations and conclusions are given below. This review is based on component properties and addresses whether these components individually satisfy the NRC criteria.

2.2 Waste Forms

2.2.1 High Level Waste Forms

Based on the present leach data available for candidate waste forms, the BNL staff has identified the following as the most leach resistent and therefore have the potential to contribute to both performance criteria.

- multibarrier waste forms such as ceramics coated with Al_2O_3, PyC, SiC or a combination of these and high silica glass with a sacrificial layer of non-radioactive glass,
- SYNROC,
- Sandia Titanate,
- high alumina ceramic developed for SRL waste.

However, a critical evaluation of these waste forms and their ability to meet NRC criteria will depend on a more extensive characterization of the waste form properties.

The staff believes that standardization of leach tests under a wide range of repository conditions is required so that more valid comparisons of waste forms can be made. We also believe that a major effort should be expended to understand the mechanisms of leaching in various alternative waste forms. Mechanistic studies would allow an assessment of

- the usefulness of accelerated tests;
- the ability to predict long-term behavior,
- the interaction of different phases in various waste forms and the difference in the leach behavior of the various phases.

In order to acquire a comprehensive understanding of waste form behavior systematic control and variation of not only Eh and pH is necessary but also of the concentration of dissolved gases, the total pressure, the flow rate, the temperature and the solution composition is required. Waste forms should be characterized before, during and after leaching. This will require the development and standardization of reliable accurate methods for surface and solution analysis.

In order for the DOE to take credit for a waste form in contributing to the overall performance of the waste package it must be demonstrated that leach characteristics of small laboratory samples can be scaled to take account of the size of the waste form, flow rates and the surface-to-volume ratio. In addition, the leaching should be evaluated under conditions corresponding to the failure modes of the waste packages, i.e., water flow through pits in the canister, etc. The staff realizes that there will be sampling difficulties in leaching large, potentially inhomogenous waste forms. It may be necessary in this case to sample

a large waste form and demonstrate that such a sample is a "worst case representation" of the surface composition.

Again, independent of the studies just noted, a number of generic and specific studies are required to demonstrate that radiation effects do not adversely change the properties of the waste forms.

Of all the proposed components of the waste package, the only one the DOE will designate this year will be a single alternative waste form to borosilicate glass.[11] Detailed descriptions of the group from which this waste form will be chosen are given in the BNL Task 1 report. If the DOE expects to take any credit for the waste form in complying with 10 CFR 60, then the specific recommendations for the information the NRC will require will be greatly dependent on the waste form selected. For example in comparing SYNROC to Sol-gel coated particles, tests demonstrating the potential for controlled release rate capability would be significantly different. In the case of SYNROC, dissolution may be uniform, so that leach rate measurements similar to borosilicate glass may suffice. In the case of the coated particle where dissolution of the outer two or three surfaces would not result in release of radionuclides, a determination of failure modes may indicate long zero release induction periods followed by releases dependent upon pin-holes in the coatings, groundwater flow rates of the aquifer, etc.

2.2.2 TRU Waste Forms

The present draft criterion proposed by NRC for TRU wastes is a controlled release rate no greater than 10^{-5}/yr of the activity present in the engineered system at the time of decommissioning. Based on NRC's current definition of a waste package, it is our determination that the only components capable of complying with 10 CFR 60 are a waste form, a synthetic backfill, or an appropriate combination of the two. DOE has yet to demonstrate that a TRU waste form could in fact comply with the NRC standard. Therefore, if TRU wastes are stored in a HLW repository, DOE may choose to show compliance with this criterion by use of an appropriate backfill.

The current development in TRU waste forms will be detailed in Task 2.[12] According to this study the traditional waste forms considered for immobilization of TRU wastes (i.e., urea-formaldehyde, bitumen, and hydraulic concrete) should be disqualified from further consideration.[13] The newer waste forms being considered for TRU waste include:

- specially prepared concretes (e.g., FUETAP and cold pressed concrete),
- borosilicate glass,
- mineral and ceramic forms (e.g., actinide bearing phases of SYNROC and synthetic monazite), and
- iron-enriched synthetic basalt (IESB).

The BNL staff believes that none of the data bases for the above waste forms is currently capable of demonstrating compliance with the controlled release criterion. A summary of our Task 2 study is given below:

1. Although the problem associated with radiolysis of residual water in hydraulic concretes is in part* circumvented by FUETAP and cold pressed concretes, the primary standard for measuring the performance of these waste forms (i.e., leachability) against other candidates needs to be assessed more fully. While ^{239}Pu leach data for cold pressed concrete are promising, it is difficult to compare with other waste forms because of the unique nature of concrete waste forms. More detailed leach tests based on a range of radionuclides should be applied to determine if this waste form could meet NRC criteria and thus warrant further development.

2. While some borosilicate glasses show satisfactory performance properties for HLW, they have been found to be sensitive to the composition of TRU ash. There is a need to develop a glass composition that is less sensitive to ash/sludge composition and to subsequently demonstrate its leach behavior by standard MCC test procedures.

3. Minerals and ceramic waste forms incorporating actinides, are known to have good refractory properties and to have low water solubilities. A more detailed consideration of the effects of non-actinide constitutents in the TRU waste stream (e.g., oxides of Fe, Si, and Al) on phase formation, actinide solubilities and partitioning in multiphase assemblages should be carried out. It would be helpful to characterize each single phase component individually as well as investigate the effects of solid solution composition and alpha irradiation on the leach behavior. To allow for a valid comparison of data in asssessing the leach behavior, standard MCC tests should be performed.

4. Iron enriched synthetic basalt is presently DOE's most promising waste form for TRU wastes for the following reasons:

- it is made from readily available starting materials,
- it will accept most waste streams in the processing stage,
- it will accept high waste loadings (nominally, 40% by weight), and
- depending on the actinide concentration and phase formation conditions, the actinides will either partition into a residual glass phase or stabilize as UO_2 like phases. Both phases show low leachability for the actinides.

While IESB is a promising waste form for TRU wastes, its characterization is incomplete. It undergoes microcracking, there are no ^{239}Pu leach data and the formation of leach resistant devitrified phases has not been demonstrated on a production scale.

---

*Radiolysis associated with water flooding may still be a problem.

It is BNL's assessment that the newer waste forms being considered by DOE have not yet been developed to a stage where the waste forms can be shown to meet NRC criteria for a controlled release rate. If future DOE work indeed confirms that a waste form is incapable of meeting the release criterion then DOE may want to demonstrate compliance through the use of an appropriate backfill.

2.3 Containers

The present container research effort is centered mainly at PNL and Sandia and concentrates predominantly on Ticode 12 (nominally containing 0.84% Ni and 0.34% Mo). These corrosion studies are currently inadequate to evaluate candidate materials for 1000-year containment.

It is the staff's conclusion that the container research programs should be extended to consider other metals such as Pb and Cu, as well as common engineering alloys. The latter materials should be evaluated since their lower corrosion resistance may be compensated for by using increased wall thicknesses.

Welded materials should also be studied since their structures are very often different from those of the base material. Welds may also be more susceptible to stress corrosion cracking (SCC), pitting, and crevice corrosion than base metals.

All candidate material studies should consider the anticipated repository environment (i.e., testing should be under a range of conditions including groundwaters typical of a potential repository site and prototypic temperatures, pressures, etc.). Groundwater passing through the backfill may undergo a change in the impurity concentration and thereby affect the corrosion behavior of the container. The backfill material could also give rise to the formation of crevice regions against the container where groundwater could remain in a stagnant condition. Corrosion tests using stressed and unstressed samples placed in intimate contact with a backfill material should therefore be conducted in order to assess such metal/backfill interactions.

Gamma radiolysis of groundwater may generate hydrogen which could cause embrittlement of some container metals. This potential degradation effect should be studied in depth to quantify the loss in ductility.

Candidate container materials should be tested under prototypic repository conditions, for extended periods of time to determine if localized attack (e.g., pitting, crevice corrosion, and SCC) occurs. Such long-term testing (up to several years) does not appear to be included in the DOE effort. The development and critical evaluation of electrochemical methods (e.g., AC potential scanning)[10] should be considered as a means of determining susceptibility to pitting.

The problems of using accelerated tests to evaluate the corrosion behavior of a candidate material should also be addressed. New accelerated test methods and ways to interpret the data should be developed so that an extrapolation of these test results to prototypic conditions and geologic times can be justified. Ideally, accelerated and non-accelerated tests should both be

conducted so that accelerated test results can be correlated with actual corrosion behavior.

The minimal requirements for a data base to predict long-term behavior should be such that variations in failure times, pit densities, pit and crack proagation rates, general corrosion rates, etc., can be quantified on a firm statistical basis. In addition, enough data must be accumulated so that the mechanisms of corrosion are understood. Unless the mechanisms are understood, accelerated test methods may be invalid for predicting long-term behavior. It must also be demonstrated that for the accelerated corrosion tests the corrosion mechanisms are not different from those occuring under prototypic conditions.

Finally, different design concepts should be investigated. Multiple containers with or without suitable annular fillers between the containers may lead to prolonged life of the container system since it would be necessary to repeat the induction and propagation of the corrosion failure process at each individual container surface.

2.4 Backfill

The appropriate choice of a backfill material may be one means by which both 1,000-year containment and a controlled release rate may be achieved. Most of the present effort within the DOE is centered on the use of clay minerals and other aluminosilicates as backfill material. Some effort, however, is being expended to consider mixtures of backfill materials designed to retard anionic (TcO_4^-, I^-, and SeO_4^{-2}) as well as cationic radionuclides.

The primary emphasis has been on the use of montmorillonite as the main component of a backfill to limit groundwater flow to the waste package. By limiting the flow of water to the waste package, the onset of container corrosion may be delayed and the rate of corrosion reduced. Reduced groundwater flow may also restrict radionuclide transport to a diffusional process.

Minerals which contain metals [e.g., $Fe_3(PO_4)_2$] in a reduced state, minerals which interact with the anionic species, and activated charcoals or graphite have been proposed to retard the movement of anionic radionuclides. Reduced metal minerals could also buffer the near field redox conditions thereby reducing canister corrosion and maintaining the actinides in their reduced, most sorptive state.

Quartz as a component of the backfill has also been investigated. It increases the thermal conductivity of the backfill and may, therefore, enhance the lifetime of the waste package by reducing its temperature. It has also been found to add to the mechanical strength of the backfill.

There is preliminary information available on the sorptive properties of mixtures of zeolites and clays. The data indicate that a beneficial synergistic effect occurs in some cases and results in a greater sorptive behavior than expected based on the sorption properties of individual minerals.

Backfills tailored to a specific repository environment have also been investigated. In a salt environment, synthetic mordente zeolite, sodium titantate, and activated charcoals, provide a radionuclide sorptive barrier. However, sorption of fission products and anionic radionuclides was inadequate. Crushed basalt is being studied as a potential backfill material for a basalt repository.

None of these investigations directly addresses the ability of backfill material to meet NRC's proposed criteria, nor are the available data sufficient to demonstrate compliance. For those backfill materials which have a potential to meet the NRC criteria, data on radionuclide specific breakthrough times under varying flow rates should be generated. Data on radionuclide diffusion coefficients and retardation factors for various candidate backfill materials under varying repository conditions should also be generated and used to evaluate the backfill in terms of NRC's performance criteria.

While evidence exists to indicate that some clay minerals and zeolites may hold up radionuclides more effectively with time, very little work exists on the effects of aging on the fixation of sorbed radionuclides.

In addition, the thermal and hydrothermal stability of backfill materials in a range of repository conditions (e.g., temperature and groundwater) should be investigated. Research on the thermal stability of clays and zeolites under hydrothermal conditions indicate that many may be unsuitable for use in a HLW repository because they dehydrate at high temperatures. The effects of dehydration as well as alternate wet and dry cycles on the sorptive and swelling properties of a backfill need to be evaluated.

In the case of multicomponent backfills, the chemical compatibility of the mixture components under repository conditions, and the effects of the presence of additional minerals on the overall performance of the backfill must be studied. For anion sorbing components, the effects of changes in the repository environment (e.g., Eh and pH variations) on their sorbing capacity should be investigated.

The ability of backfill materials to control groundwater intrusion and inhibit corrosive attack of the containers should be assessed. Synthetic materials such as zeolites and titanates through proper selection of the mass, volume, shape, and packing densities may be useful in predeterimining and controlling the groundwater flow rates and patterns. The effects of radiation on the sorptive properties of backfill materials under repository conditions must also be studied to assure the performance of the backfill during the 1000 yr containment and subsequent controlled release periods. Finally, potential interactive effects between the backfill and container materials under repository conditions must also be addressed.

2.5 Whole Package Testing

The DOE performance assessment program for the waste package is primarily concerned with determining if any synergistic effects occur between various waste package components. Whole package tests have somewhat different controlling variables and behavioral effects compared to component tests. For example, the determination of migration of ionic species at the interface of components and

the characterization of any alteration products formed are particularly important aspects of whole package tests as they may explain changes in the leach rates of a waste form in the presence of other package components. Two types of package tests are being conducted. The PNL test is closest to a failed package, but we believe that the control of variables (pressure, temperature, Eh, pH, etc.) may be inadequate. Other "package" tests are designed to study the interaction of two components such as the waste form and host rock.

BNL believes that these particular tests are only a source of qualitative information on possible interactive efforts and any information generated will not be able to show compliance with a controlled release rate criterion. It is recognized, however, that such whole package and bi-component tests are necessary to show the overall compatability of any components contemplated as part of the waste package. It is recommended, therefore, that a more realistic design of a failed package be developed; for example, a container breached by accelerated local corrosion. Better control of variables (Eh, pH, flow rates, temperature, and pressure) is also necessary. It is also recommended that bi-component test programs include, for example, waste form-container, container-backfill and backfill-host rock evaluation. It is necessary in whole package and bi-component tests to systematically investigate the correlation of ion-specific leach behavior to ion migration in solids and the types and properties of alteration products.

2.6 Modeling of Package Performance

For a "strong link" approach to package behavior, a conservative estimate of the time for package failure can be made by measuring the time required for this strongest component to fail. This technique is useful when it can be demonstrated that adverse interactions between adjacent components do not give a failure time that is less than that determined for the single component along. When this approach cannot be used it will be necessary to integrate the results of laboratory tests on single components to obtain a release rate for the whole package.

Any modeling effort requires assumptions on failure modes and estimates of whole package release rates based on component behavior. Failure scenarios would include consideration of the sorptive behavior of the backfill medium as a function of environmental conditions, failure modes for the container in terms of the type of corrosion failure (e.g., local penetration and catastrophic container failure), and leach behavior under a variety of environmental conditions which are based on the way the container is breached.

The models being developed at SAI, Los Alamos, and PNL are being developed based on the conditions given above. These models have yet to produce a reasonable prediction of package behavior because of the limited amount of experimental data. A probabilistic approach (e.g., that of Pritzker and Grassman[14]) may complement these models by considering a probabilistic description of experimental uncertainties. It is the staffs opinion that, while these modeling efforts have yet to give a realistic picture of the package behavior, they should be continued and a comprehensive model that incorporates both the experimental data and the probabilistic description be pursued. In this way it is hoped that quantitative, rather than qualitative, data will be produced.

3. RECOMMENDATIONS ON SAMPLE (TICODE 12-BOROSILICATE GLASS) WASTE PACKAGE

The staff believes that a waste package can meet 10 CFR 60 performance criteria through the use of high integrity components or by properties specifically related to the design, rather than the components of the package. The DOE has not designed a package design for HLW. However, the following section evaluates the information available for a borosilicate glass waste form and a Ticode-12 container, presently the components receiving the major efforts in DOE, with respect to their capability to satisfy licensing criteria.

3.1 Performance of Borosilicate Glass

In attempting to assess whether borosilicate glass can at present, or has the potential in the future, to comply with existing performance objectives, a minimal number of variables were considered in addition to those given in Section 2.2.1*. The view taken here is that if these variables preclude assigning credit to this waste form in complying with licensing criteria then other considerations could be delayed for future evaluations. The properties to be considered are:

(1) Overall leachability

(2) Radionculide specific leachability

(3) Leachability dependence on water composition

(4) Leachability dependence on waste composition

(5) Leachability dependence on water flow rates

(6) Leachability variations with time

(7) Leachability dependence on radiation stability

(8) Uncertainties and reproducibility in each of the above

(The summary presented here is based on the technical review given in the BNL reports on Tasks 1, 2 and 4).

It is the staff's opinion that the existing data for any one of the first seven types of studies listed are sufficient justification to eliminate borosilicate glass as a means of achieving 1000-year containment. Taking the seven items in toto, we believe that it is unlikely that future work will

---

*Leachability as a function of wide variations in temperature was not explicitly considered. Borosilicate glass is evaluated only in terms of its ability to contribute to a controlled release rate, at a time (approximately 1000 years) when the temperature in the repository is near ambient. We recognize that water ingress into the repository may cause small local variations in temperature.

remove the adverse properties of this waste form with respect to 1000-year containment.

The staff has also attempted to assess whether the available data on this waste form indicate a potential for long-term controlled release rates. We believe that before this waste form should be considered as a candidate for controlled release rates of about 1 part in 10^5 per year, the leach rates should be at least several orders of magnitude less than the best results presently available. It is our opinion that this reduction would be required to compensate for the uncertainties due to radiation changes, variations with pH and water compositions, variations with composition and radionuclide specific surface and diffusion effects and, in general, uncertainties associated with lack of reproducibility.

In summary, our present evaluation is that no credit should be given to borosilicate glass for passing present regulatory criteria. In addition, we believe that the DOE may have to demonstrate that in using this waste form in a package, it does not, in fact, cause adverse effects in the container system because of unexpected interactions.

Borosilicate glass is not the only waste form being considered by the DOE. Other waste forms such as SYNROC, the titanates, coated particles, and glass with a sacrificial layer of nonradioactive glass are still being considered as alternative waste forms. At a recent DOE meeting,[15] the Sol-gel coated particles developed at ORNL showed release rates below detection limits. In principle then, as has been stated, the DOE could decide to develop this alternative waste form and show that it complies with 1000-year containment and potentially 10^{-5}/year release if the failure mode can be evaluated. Again, DOE must, at the very least, fully address the eight properties listed above as well as demonstrate that the behavior of the waste form in a package does not lead to any synergistic effects.

3.2 Container

A detailed review of DOE's canister program will be given in the BNL Task 1 report. Currently the major emphasis in the DOE is on Ti/Ti alloys for the container. This choice is based on work generated within the DOE community (Sandia and PNL) and the Swedish KBS-I[9] waste package. It is the staff's position that the contention that Ti can satisfy the 1000-year containment criterion is based on the Swedish literature review and analysis. Although the data generated in the DOE programs are consistent with the Swedish analysis, they are not extensive enough to give reasonable assurance for containment. For example, some of the problems that must be addressed further are:

(1) Is Pb required to prevent radiolysis and hydrogen attack of the Ti?

(2) Do Ti and Ticode-12 behave satisfactorily in all proposed repository environments? Most of the data presently available is for a salt repository.

(3) Are H_2 embrittlement and SCC potential failure modes for Ti or Ticode-12? Although preliminary experimental evidence has shown no indication of this, the staff believes that the DOE programs have not developed adequate justification to eliminate these mechanisms as potential failure modes.

(4) Can the data be extrapolated to predict long-term behavior in any repository environment? The staff believes that presently the data base does not warrant such an extrapolation (even for a salt repository). Although the DOE community (e.g., the MCC) is addressing the type of tests necessary to make the extrapolation, the ability to do so does not yet exist.

We would like to point out that if future work uncovers a major problem with Ti or Ticode-12, there is no other major program on alternative materials that will generate the data needed to qualify them for 1000-year containment.

These results taken in conjunction with the staff's evaluation of the borosilicate glass waste form indicate that a waste package comprised of borosilicate glass in a Ti or Ticode-12 container cannot now, be used to show compliance with the 1000-year containment criterion. This conclusion is based on the current data available for individual waste package components and assumes that they are independent, non-interacting barriers. The staff does not wish to imply that other designs using borosilicate glass and Ti containers could not satisfy the performance objective of 1000-containment. A new design concept, such as borosilicate glass in a series of thin walled Ti cans, has potential to meet this criterion but would have to be extensively evaluated.

We wish to note that the staff has recently submitted a position paper to the NRC in which we have recommended what we believe are the best individual waste forms, containers, and backfills. In addition to describing a high priority waste package with combinations of optimum components, the staff has described what we believe is a waste package capable of complying with 10 CFR 60 and which uses conventional materials and existing technology. A summary of our arguments is given below:

It is our strong conviction that properly selected combinations of high integrity waste forms and high integrity containers should provide containment well in excess of 1000 years.

The components that were selected as illustrative examples of feasibility for 1000-year containment are:

1. A BNL modification of the Swedish Ti-Pb container design, viz., a Ti-Pb canister in a Ti-Pb canister in a Ti-Pb canister....with or without buffering material such as outgassed graphite between the containers.

2. Coated waste particles where the coatings are similar to those on the TRISO fuel particles used in high-temperature, gas-cooled reactions (HTGRs).

3. Borosilicate glass with a sufficiently thick coating of nonradioactive compatible glass might be an alternative waste form which could provide 1000-year containment if an adequate technology was developed.

The BNL staff has evaluated the Swedish Ti-Pb container design for NRC and agreed that it can maintain containment of radionuclides in excess of 1000 years for the environments considered in the Swedish reports. Since the hypothetical loss of integrity is expected to occur by corrosion of the outer surface and the stepwise propagation of failure through multiple container walls, it should be intuitively obvious that the proposed BNL design should provide enhanced containment for lifetimes greatly exceeding 1000 years.

We also consider that quality assurance testing of such a package can be relatively straightforward. We would recommend helium leak testing, standard non-destructive physical testing such as dye penetrant tests of welds, eddy current testing, radiography, ultrasonic testing, etc. Each of these tests would be applied to the individual containers as they are assembled to form the waste package.

Modifications, for example, of the can-in-a-can-in-a-can concept with alternative materials to those specified above would be acceptable provided an adequate data base is generated prior to licensing.

If a continuing comprehensive materials evaluation program does not generate information that adversely contradicts the existing state of knowledge, then for this specific container design, we suggest that the type of testing discussed above may be adequate for licensing if it is accompanied by documentation of the data and models used to make the materials design choices and predict their behavior. This documentation, perhaps in the form of a licensing topical report, would be reviewed by the NRC and/or its consultants as part of the licensing process.

In the case of a waste form that has high potential to provide independent 1000-year containment, we have selected as an illustrative example nuclear waste particles coated in a manner as similar as possible to TRISO fuel particles developed for HTGRs. For the coated particle the physical, chemical, mechanical, and structural properties have been studied extensively over the last 20 years by hundreds of scientists at General Atomic company, ORNL and various laboratories in Germany, Britain and Japan.

We are convinced that a properly designed waste form of this type can by itself readily achieve 1000-year containment. If in addition the coated waste form is encapsulated in graphite rods and/or graphite containers, this will lead not only to an additional leaching barrier but also minimize dispersibility.

If continued research in applying this technology to nuclear waste demonstrates the expected success, then the tests required for licensing should be very similar to those NRC has already considered for the performance behavior and quality assurance of HTGR fuel.

Again we wish to emphasize that if this type of waste form is combined with the container system discussed here, NRC criteria can be readily achieved and the licensing acceptance tests are relatively straightforward, specific, and invoke nothing but established technology.

We also note that along with the above system BNL has also seriously considered that synthetic zeolites and/or titanates have the potential for 1000-year containment. In this case we do not feel the existing data base is adequate to propose this without further experimentation. We do feel, however, that this system may have the highest potential for achieving the controlled release rates required by the NRC.

The properties of sample waste package components have been addressed. Again the DOE could choose to consider other package design concepts that may rely on conventional materials. In this case, if compliance by one component cannot be demonstrated, the whole package must be shown to comply with NRC criteria. If, for example, the DOE opted to use stainless steel containers with radionuclide retardant materials as fillers (in the annular spaces), and borosilicate glass as a waste form, the package must be shown to comply with 10 CFR 60 1000-year containment. Under these circumstances, the staff would recommend considering minimally:

(a) How long will the containers survive in a repository environment?

(b) What is the failure mode of the package and once breached, how will the individual components behave? Can the radionuclide retardant filler successfully bind up the fission products as well as the actinides? How does it interact with the waste form? What are the effects of Eh, pH, etc.?

(c) How much credit can be given to the waste form in such a package?

4. SPECIFIC NRC INFORMATIONAL NEEDS ON SAMPLE WASTE PACKAGE COMPONENTS

The NRC has requested that BNL identify, in condensed tabular form, information that may be required for licensing. They specify a waste package based on borosilicate glass and a Ticode-12 container for this evaluation. The information needs specified are based on present knowledge. It is expected that the tables will change as further understanding of waste package component behavior is acquired.

Under the proposed 10 CFR 60, if the DOE does not take credit for performance of individual components, it is at present not obvious what component information the NRC will require to license a waste package. BNL recognizes that the most recent draft of 10 CFR 60 includes discrete backfill as a waste package component. Although various types of discrete backfills may play important roles in allowing the waste package to pass licensing performance objectives, no table is given here for any specific backfill. Also DOE has not yet decided upon a waste package design either from selection of components or from size or geometry considerations. The tables therefore cannot denote information that may depend

upon particular choices of dimensions. The tables are based on assumptions that the components do not interact. Possible adverse synergistic effects may occur. These will have to be determined by future research after specific waste package designs are selected by the DOE.

Since borosilicate glass has a finite release rate it is obvious that uncoated borosilicate glass will not give 1000-year containment. Table 1 lists examples of the type of information the NRC might require for licensing if the DOE intends to take credit for borosilicate glass being solely responsible for determining the controlled release rate. We believe it is too early to address the difficult problem of what relative contributions can be assigned the individual components to the overall release of a complex and as yet unspecified waste package.

BNL is not aware of any information indicating that properties of Ticode-12 would allow it to be a candidate for very long term controlled release. Therefore, Table 2 lists examples of information the NRC might need if the DOE claimed 1000-year containment was due solely to a Ticode-12 container assuming it will not interact with other waste package components.

We wish to repeat our reservations concerning the significance of these tables. We refer to our past position (Letter Report on Applicability and Limitations of Corrosion Data for Predicting Long Term Containment - M. S. Davis and D. G. Schweitzer) in which we stated our concerns on the limitations of small sample corrosion data and our views that the most likely ways to satisfy 10 CFR 60 requirements were with data based on total package properties rather than on individual components.

We also wish to recall that while we stated that borosilicate glass cannot be given credit for containment, the staff has pointed out that the addition of a relatively thin non-radioactive glass layer to borosilicate glass may be one means by which the potential for the borosilicate glass waste form to meet 1000-year container may be greatly enhanced. In combination with properly designed canister systems and correctly chosen backfills we feel the 1000-year criterion can be met. The type of information the NRC may require to license such a package may or may not correspond to that denoted in the tables.

Table 1

Information Needed to Assess the Ability of Borosilicate Glass to Comply With the Controlled Release Rate Criterion

Repository Information	Component Information
(1) Temperature	General:
(2) †Groundwater/Repository Water (a) flow rate (b) pH (c) Eh (d) chemical composition (e) dissolved glasses (f) change in water chemistry due to corrosion product, precipitation, host rock interaction (g) effects of radiolysis (h) erosive properties	(1) Composition (a) waste composition (changes due to transmutation during containment period* (b) waste loading
(3) Mechanical Property Data (a) pressure (b) friction (thermal changes)	(2) Size, Shape (i.e. leachability of 1000-yr old waste glass scaled to realistic WF), Surface Area, Surface Film*
	(3) Effects of Radiation and Devitrification
	(4) Compositional Change - Devitrification, Phase Separation
	(5) Leaching as Function of Failure Mode of adjacent components (e.g. pits in container, cracks in overpack)*
	(6) Leaching as Function of Corrosion Product Accumulation*
	(7) Mechanical Characteristics of Glass After Failure of Containment
	(8) Leaching of Glass Vs. Change in Backfill After 1000-yr Exposure to Radiation (way backfill may condition the water)*
	(9) Kinetics of Leaching Mechanism Specific Leachability and Release Rate Dependence on (a) temperature (b) flow rate

†Groundwater is defined here as the water associated with the site while Repository Water is the groundwater after it has been altered by the engineered barriers.
*Indicates little or no work being done by DOE.

Table 1 Cont'd.

Repository Information	Component Information
	(9) Kinetics of Leaching Mechanism Specific Leachability and Release Rate Dependence on (Cont'd.) (c) Eh (d) pH (e) ion composition (waste form and water (f) radionuclide specificity with time (g) devitrification (h) reprecipitation (i) film formation and removal* (j) erosion (k) phase separation (l) changes due to container corrosion* (m) changes due to backfill chemistry variations with time* (n) stress formation or annealing (o) diffusion through depleted surface* (p) radiation effects in glass (q) radiolysis of environment* (r) transmutation of waste in glass*

*Indicates little or no work being done by DOE.

Table 2

Information Needed to Assess the Ability of TiCode-12 to Comply with the 1000-Year Containment Criterion

Repository Information	Component Information
(1) Temperature (a) repository profile with time (b) container profile with time (c) changes due to water ingress	(1) Corrosion Mechanism(s)* as function of e.g. (a) temperature (b) changes in groundwater chemistry (by radiolysis, accumulation of corrosion products, changes induced by change in backfill) (c) surface properties of container (d) Eh (e) pH (f) flow rate (g) hydrogen conc. from radiolysis (h) other products from radiolysis (i) stress distribution (j) crevice properties (k) weld composition (l) weld integrity (m) time
(2) Pressure (a) lithostatic (b) hydrostatic (c) effect of temperature	
(3) Vault Characteristics (a) creep in salt as function of temperature, time (b) fissure formation (1) precipitation of silicates (2) migration of brine (3) deposition of corrosion products	(2) Statistical Verification* of (a) corrosion mechanism(s) in base material and weldments
(4) Repository and/or Groundwater (a) composition (b) Eh (c) pH (d) dissolved gases (e) temperature (f) flow rate (g) erosive properties (particulate composition)	(3) Statistical Verification of Probable Failure Modes*
(5) Geometry of Host Rock (a) size, shape, density* (b) void space* (c) movability, inertia of package	(4) Mechanical Stability as Function of: (a) time (age) (b) temperature (c) water chemistry and changes in H_2O chemistry (d) pressure

*Indicates little or no work being done by DOE.

Table 2 Cont'd.

Repository Information	Component Information
(6) Discrete Backfill (a) composition* (b) adsorption* (c) ion-exchange* (d) waste package packfill/ interface properties* (e) density* (f) water flow properties (g) movability* (h) inertia* (i) erosive properties* (j) chemical properties* (k) changes with time (l) reversibility with wet and dry cycling* (m) temperature changes* (n) radiation stability*	(5) Mechanical or Chemical QA Date on (a) stress analysis (b) fatigue data (c) delayed fracture (H_2O conc. and stress) (d) SCC thresholds* (e) linear-elastic fracture mechanics data* (f) residual oxygen and hydrogen content

*Indicates little or no work being done by DOE.

5. SUMMARY/CONCLUSIONS

In summary, the BNL staff believe that the present DOE programs on borosilicate glass and Ti (or Ticode-12), have not generated the data base adequate for showing compliance with either the containment or the long-term release rate criteria of 10 CFR 60. It is possible, however, that other high integrity components could be developed to meet one or both of these requirements in the near future. The other generic approach for showing compliance with 10 CFR 60 is through generation of a data base on various package designs. We feel that presently the most likely means available for satisfying 10 CFR 60 with a single package component is through properties of a discrete backfill.

Our reviews and evaluations of DOE backfill work have been limited because backfill was not always considered part of the waste package. Nevertheless, the staff still supports its past evaluation[16] that existing data on natural backfills indicate that water flow properties through them are not predictable. Uncertainties exist because of irreversible swelling and shrinking properties resulting from sequences of wetting and drying.

Consequently, we do not feel that existing data on natural backfills will be acceptable as the sole source of satisfying containment and the long-term release rate criteria.

We have, however, evaluated in detail[16] a synthetic zeolite system which we believe is an example of a backfill with a potential to satisfy both criteria. Again we wish to note, that in this particular case, it is the staff's opinion that existing technology and data for this system from water reactor purification results and from oil industry applications, indicate that major development programs may not be required to qualify this material for licensing applications.

6. REFERENCES

1. Presidential Policy Statement, February 12, 1980.

2. Report to the President by the Interagency Review Group on Nuclear Waste Management, TID-29442, March 1979.

3. Ibid, p. 117.

4. PR-50,51 (44FR61372) Proposed Rulemaking on the Storage and Disposal of Nuclear Waste, DOE/NE-0007, PI-3, 1980.

5. "NWTS Waste Package Program Plan," ONWI(96), Vol. I, 1-3, August 29, 1980.

6. Ibid, pp. 3-2, 3-3.

7. Code of Federal Regulations, 10 CFR 60, "Disposal of High-Level Radioactive Wastes in Geologic Repositories," Proposed Rule, July 8, 1981.

8. E. Mattson, "Corrosion Resistance of Canister for Final Disposal of Spent Nuclear Fuel," Scientific Basis for Nuclear Waste Management, Vol. 1, Plenum Press, N.Y., pp. 271-81 (1978).

9. R. Dayal, et al., Waste Package Overview Draft Final Report, BNL-NUREG-27961R, July, 1981.

10. T.M. Ahn, et al., Test Development Review Draft Final Report, BNL-NUREG-27773R, June, 1981.

11. Revised DOE budget, April 1981.

12. G. Bida and D. R. Mackenzie, "Alternate TRU Waste Forms," Final Report, BNL-NUREG-27715R, June, 1981.

13. G. Bida, R. E. Davis, and D. R. MacKenzie, "Alternate TRU Waste Forms," BNL-NUREG-27715, April 1980.

14. A. Pritzker and J. Gassman, "Applications of Simplified Reliability Methods for Risk Assessment of Nuclear Waste Repositories," Nuc. Tech. 48, 289 (1980).

15. HLW Technical Review, Alternative Waste Forms Peer Review, Sponsored by U. S. Department of Energy, Office of Nuclear Waste Management, Atlanta, GA, May 18-19, 1981.

16. T. M. Ahn, R. Dayal, R. J. Wilke, "Evaluation of Backfill as a Barrier to Radionuclide Migration in a High Level Waste Repository." To be submitted to "Workshop on Research and Development Needs in Backfills for Underground Nuclear Waste Management," sponsored by National Bureau of Standards, Gaitherburg, MD, April 13-14, 1981.

APPENDIX 1

NWTS PROGRAM OVERVIEW: M. S. Davis

This appendix is based on our understanding of the DOE organization as presented in DOE publications. Although we have stated that there does seem to exist a centrally organized waste package program we would like to point out that it is not clearly articulated. Further clarification or revision by the DOE may alter or even negate our analyses and conclusions.

NWTS PROGRAM OVERVIEW: M. S. Davis

INTRODUCTION

At this time the existing national waste management objectives are based on the Presidential Directive of February 12, 1980, which in turn was the result of recommendations made by the Interagency Review Group.[1] As noted in the IRG report straightforward execution of NRC's responsibilities is difficult because of the requirement that NRC regulations conform to an EPA standard that has yet to be published. In order for the DOE to develop the data base required for licensing in a timely fashion, the NRC has developed tentative criteria in advance of the EPA standard. These criteria and performance objectives are designed to assure safe isolation of high level wastes through the use of engineered and natural barriers in conformance to presidential recommendations.

In reviewing factors needed for the licensing of high level repositories, we reviewed the need for a centrally organized waste package effort and determined whether the present and planned DOE program is consistent with the needs and goals of this effort. It is the staff's belief that the DOE has in fact attempted to structure a centrally organized network for development of a waste package.

The NWTS Programs (National Waste Terminal Storage) within the Division of Waste Isolation conducts the Waste Package Program. The WPP's primary objective[2] is "...to plan and implement the technology, development, design, and production of waste packages for the isolation of nuclear wastes in deep geologic formations," within the context of the overall NWTS performance objectives, general performance criteria[3] and future regulatory (EPA, NRC) criteria.

In order to successfully manage the course of the Waste Package Program, an NWTS Waste Package Program Plan[4] was issued in August 1980. This plan is meant to establish a strategy that would:

- Avoid duplication of effort and facilitate development.
- Identify future needs.
- Delineate waste package goals.
- Help define future funding requirements.

This plan is to be viewed as an evolving strategy that describes[5] "...an orderly interrelated program and its subelements which will result in the development of geologic waste isolation packages for the NWTS program..." and "...to demonstrate that the waste package effort is integrated with other NWTS program efforts underway to find suitable sites and to develop the repository facilities and equipment; and to provide other DOE lead program offices with a means for judging the mutual benefits of the tasks underway in related waste packaging areas and assist in the integration of these tasks as necessary."

This plan evolved because of a recognition[6] by the Department that it is "...apparent that there is a strong need for integration of the activities in the NWTS Program and between the NWTS Program and other DOE waste management."

The Nuclear Energy Waste Program (NEW) and the NWTS Program are shown in Figure 1.* Figure 2a illustrates the major planning documents of the NWTS Program. The Waste Package Program Plan (WPPP) is meant to be consistent with the overall NWTS Plan[8] and the Earth Sciences Technical Plan.[9] The general management and coordination for the development of the technology and for geologic exploration on non-DOE lands is the responsibility of the Battelle Office of Nuclear Waste Isolation (ONWI), a branch of the Richland-Columbus lead office. The program management activities for the NWTS Program are relegated to four subdivisions (Figure 3). Geologic exploration and technology development are administered in separate components of the ONWI structure. This, then, is the central network for integrating the DOE waste package effort. It is within ONI that all elements of the NWTS Program must be

---

*Recent information[7] indicates that there is a new Battelle Project Management Division. The Office of NWTS Integration (ONI) has been formed to coordinate and integrate the NWTS Program. The Waste Package Office is now under the ONI. Furthermore, it is our understanding that major revisions will be made to NWTS (96).

integrated, and it is through ONWI that other DOE nuclear waste efforts related to the waste package should formally coordinate their efforts. A complex network has been established to achieve interface and coordination between the NEW divisions and within the NWTS Program. Interface coordination (i.e., the act of bringing together independent systems to communicate with each other and act in a "concerted" way) is meant to be achieved by the establishment of Interface Control Boards at the lead office level, and a system of Interface Control Groups and Interface Working Groups, ICGs and IWGs within the NEW and NWTS Programs (Figure 4).

The lead office ICBs have been established by DOE to coordinate the interaction between the various elements of DOE's Nuclear Waste Management Program (a charter is given in Appendix B). These four ICBs are under the "guidance of the Waste Management Steering Committee[10] in which rests the final decision making authority." The ICBs (Isolation, HLW, TRU and Transportation) effect the "baselining" process within NEW programs, i.e., the act of formally establishing and controlling program documents which contain "...criteria, requirements, objectives, schedule, cost, and deliverable definitions."[11]

A formal agreement, Appendix A, between ONWI and the Savannah River High Level Waste Program was signed in December 1979. (A similar agreement is being formulated between ONWI and TRU-WM ICB). The agreement delineates the separate responsibilities of the two programs as well as those areas where a joint organized effort will benefit both. For example, it is explicitly stated in this agreement that "canister related projects should be closely coordinated through the interface control organization to maximize the benefits to the production, transportation, and isolation programs." This agreement also recognizes ONWI's responsibilities for the development of "Design Criteria and Specifications for Repository Emplacement," i.e., ONWI has lead responsibility for managing all phases of the effort to get a licensed repository. Within the context of this responsibility ONWI recognizes that it should provide SR/HLW "with definitive design criteria to allow SR/HLW waste form and/or canister investigations to proceed in an orderly manner."

The Richland-Columbus Office, lead office for the Waste Isolation Program (NEW/I) has established the Isolation Interface Control Board (I-ICB). This Board serves two functions:

- it is charged with establishing an interface with other NEW program ICBs and appointing representatives of the waste isolation programs to IWGs formed by other ICBs;

- and within the NEW/I division it must also effect interaction and control among the various waste isolation programs (NNWSI, BWIP, ONWI and the Subseabed Program).

Since ONWI has lead managerial responsibility for the NWTS Program, the I-ICB is chaired by ONWI personnel. Coordination of all the elements of the NEW/I division by the I-ICB will presumably be achieved by a formal system of

standing ICGs (Interface Coordination Groups), and temporary IWGs (Interface Working Groups) formed to consider a specific issue. The I-ICB has presently established seven permanent ICGs (Figure 4). These are chaired by ONWI personnel and generally include representatives from BWIP, NNWSI, WIPP and other organizations (e.g., SR/HLW or TRU programs) on an as needed basis. For example, the waste package ICG (WP-ICG) is chaired by the ONWI Waste Package Program Office Manager. It is envisioned that this will give maximum coordination between the Waste Package Program Office, which manages the waste package activities and the WP-ICG which coordinates the waste package related activities within the NWTS Program.

The ICGs consider interaction and technical/programmatic questions which may involve "...design, standards specifications...tests, procedures...or any other aspect of the waste isolation programs in which the NWTS Subseabed and WIPP activities have material interest, and...mutual responsibility.."[12] For example, the WP-ICG is to "...identify, delineate and evaluate waste isolation technical and programmatic issues relating to the waste package which represent an interface with or an impact on two or more of the waste isolation programs."[13] The WP-ICG specifically addresses issues related to the waste package work breakdown structure and is active in baselining criteria, reference data, specifications and other material related to the waste package effort through a review and approval activity. As an interface group it also is meant to interface with other ICGs "...as appropriate for implementation of waste package data base needs," as well as identify "...new issues pertinent to the waste package" and develop "recommendations concerning these issues for submittal to the I-ICB."[13] Thus far, there are two major issues which have been identified[13] by WP-ICG as having a major impact on the waste package efforts. These are a definition of waste forms for spent fuel and the need to establish TRU waste requirements and incorporate them in the waste package program plan.

On completing its review and approval activity an ICG formally submits its findings to the I-ICB. The ICGs working in conjunction with the I-ICB are therefore meant to coordinate the activities and needs of the waste isolation programs and insure that technical decisions made by any of the NWTS programs, the Subseabed Program and WIPP are compatible with the other waste isolation programs. The ICBs in their turn are meant to coordinate the waste management efforts of the NEW Program. An illustration of how the internal NWTS interface network functions is as follows: The Reference Repository IWG (RR-IWG) was established by the I-ICB to develop and recommend generic reference repository conditions for each host rock that is being considered for a repository. The RR-IWG is utilizing input from the "Expected Repository Environment" (ERE) task as well as other sources. Their report will be submitted to the Repository ICG (R-ICG) for review and approval. Once the R-ICG has approved the report it will be forwarded to I-ICB for baselining. Once baselined, this information will be forwarded to other ICBs as per their interface agreements. The function then "...of an ICB is mainly administrative, the function of a working group is mainly technical."[14]

Although a clear definition of coordination between tasks in the NWTS Program has yet to be established, some intertask cooperation is visible between the Quality Assurance Department (QAD), which interacts with the QA-ICG, and the Waste Package Program Office, to which the QAD lends support.

Within the NEW Program we have already noted the formal agreement between ONWI and SR/HLW programs, as well as one pending between ONWI and the Albuquerque Office which coordinates the TRU Waste Management Program. It should be noted that ONWI has representatives on the SR/HLW Program Defense Waste Processing Facility Waste Form IWG and the TRU Waste Program Migration Model IWG.

There are presently five subtasks in the WBS of the Waste Package Program (Figure 2b):

- Baselining
- Waste Form
- Barrier Materials
- Design and Development
- Performance Evaluation.

The baselining subtasks formulate the "...major control and guidance documents, waste package information, criteria and specifications"[11] that overall must conform to DOE's seven objectives and generic criteria as well as eventually conform to all regulatory standards. The information developed in this subtask is used by all the tasks and it is the main responsibility of the I-ICB to develop and coordinate this information. An independent committee comprised of DOE personnel, the Waste Materials Steering Committee (WMSC) has the ultimate management decision making authority. The ICBs report to the WMSC via their respective field offices and headquarter organizational components. The Materials Characterization Organization, consisting of the Materials Characterization Center (MCC), the Materials Review Board (MRB), and the Independent Measurement Standards Laboratory (IMSL), also reports directly to the WMSC. The MCO was established as an independent organization with no management functions. "Its sole purpose is to provide a quality assurance and validation function to assure a consistent technical approach to materials testing and documentation of data to support safety analyses, design of waste packages and other equipment, and the eventual operation of repositories."[15] The MCC is to be a central focal point for the material data base and supporting documentation. "The environmental conditions of the repositories and the materials of interest will be defined by the NWTS Program. Through testing activities the MCC will assist in identifying the needs for approved materials specifications and development of materials. The MCC will coordinate its functions with DOE, DOE contractors and other technical groups to avoid duplication of effort and to ensure completeness of the Materials Testing Program. It will define its test procedures using acceptance criteria and waste repository requirements defined by other appropriate programs."[16] We assume then that the NWTS Program, specifically the ONWI managed I-ICB will be the organization that defines the acceptance criteria and waste repository requirements. The MCC is by charter required to work closely with ONWI to help assure "...that their (ONWI) test methods and data are approved by the MRB for inclusion in the Nuclear Waste Materials Handbook."[17]

The MRB responsibilities include "...a review of scientific and technical bases of data and test procedures, and review of the relevance of these data and procedures to the disposal and assurance criteria."[18] The MRB reports to the WMSC which determines the composition of the Board and approves membership on the Board. It has been decided that to expedite the function of the MRB, two panels will be formed whose function will be a preliminary approval of material submitted by the MCC prior to submission to the Board. These two panels may form subpanels to deal with specific assignments. The MRB may then take one of four actions:

- Acceptance or approval
- Rejection
- Return to a panel for further consideration
- Request that the IMSL give expert opinion with respect to technical issues, supplement existing data, or settle existing data disputes.

Once the material (data or test procedures) is accepted by the MRB it may be incorporated in the Nuclear Waste Materials Handbook.

The IMSL is one of the independent peer review programs established by the DOE and utilized by the NEW programs. The National Bureau of Standards Laboratory was recently contracted to act as the IMSL. In this capacity it should "...provide an independent scientific peer review of selected MCC activities and ...referee materials property data and procedures. It will also support the Waste Isolation Program in areas outside the MCO."[19] The IMSL may also interface with SR/HLW; TRU Program, ONWI and the Transportation Program.

The NWTS Program (ONWI) will have to have two major inputs to the IMSL:
- Expected repository conditions.
- Performance/acceptance criteria.

Thus there exists an interface of the I-ICB with the IMSL.

The IMSL is but one of the peer review entities utilized by ONWI in managing the NWTS Program. The Program Review Committee provides a "formal mechanism for evaluation of the Program within the broad aspects of nuclear waste management..."[20] The Technical Advisory Committee reviews the technical quality of the ONWI Program. This Committee will for example review technical data compiled by the NWTS Material Degradation Mechanism IWG and determine the feasibility of accelerated testing on waste packages and components. The Geologic Exploration Review Group and the Earth Sciences Review Group provide independent assessments in areas of the geologic exploration and waste isolation earth science programs.

There is then a centrally organized and managed structure for the design, development and production of a waste package. This organized effort coordinates programs and efforts within the NWTS Program as well as interfaces with other waste management programs and has structured into its organizational plan mechanisms for peer review.

CONCLUSIONS AND RECOMMENDATIONS

Our evaluation of the Waste Package Program Plan (with respect to the DOE structure rather than the R&D results) is that it has the potential to succeed.

We recognize that the NWTS Waste Package Program Plan is an evolving strategy which must respond not only to technology changes but also to policy changes. The organizational network which has been structured to integrate the waste package program must therefore have enough flexibility to deal with these changes. We feel that timely input by the NRC would indeed help maintain the flexibility.

We recommend that NRC and DOE consider the feasibility of having NRC representation on the WP-ICG. This could provide guidance on NRC policy and would allow for interaction in a review of technical issues. We also feel that the NRC should have input to the I-ICB. It is here that criteria and standards are developed and an interface with other NEW programs is achieved and baselined for the NWTS Program. The NRC is at present an observer on the MRB. We recommend that the NRC role be expanded to participation on the two panels established to prescreen material prior to submission to the MRB for approval.

The NRC should continue its technical evaluation of DOE efforts as this serves as a mechanism for keeping the NRC informed as well providing the DOE with a mechanism for external peer review. This type of review process would be more efficient in helping the NRC give guidance to the DOE.

REFERENCES

1. Report to the President by the Interagency Review Group on Nuclear Waste Management, (National Technical Information Services, Va.), TID-29442, 1979.

2. "NWTS Waste Package Program Plan," Office of Nuclear Waste Isolation, Battelle Project Management Division, ONWI-96, Vol. I, pp 1-3, August 29, 1980.

3. "NWTS Program Criteria for Geologic Disposal of Nuclear Wastes - Waste Package Functional Criteria," Office of Nuclear Waste Isolation, Battelle Project Management Division, ONWI-33(4) (Draft), March 21, 1980.

4. ONWI(96), op cit, Vol. I and II.

5. Nuclear Waste Isolation Activities Report, U. S. Department of Energy, Division of Waste Isolation, Washington, DC, p. 19, May 1980.

6. National Waste Terminal Storage Program, Office of Nuclear Waste Isolation, Battelle Project Management Division, ONWI-19 (Rev. 1), p. 73, December 1979.

7. Private communication, J. McDowell.

8. NWTS Program Plan, Office of Nuclear Waste Isolation, Battelle Project Management Division. Not yet available.

9. Earth Sciences Technical Plan for Disposal of Radioactive Waste in a Mined Repository, Office of Nuclear Waste Management and U. S. Geological Survey, DOE/TIC-11033 (Draft), April 1980.

10. ONWI-96, Vol. I, op cit, p. 11-5.

11. Ibid, p. 5-1.

12. Ibid, p. 5-4.

13. Waste Package ICG Action Plan, private communication, Neil Carter, March 23, 1981, see Appendix B.

14. Charter for Interface Control Boards. Appendix C.

15. ONWI-96, Vol. I, op cit, p. 11-10.

16. ONWI-96, Vol. II, op cit, p. 2-91.

17. Ibid, p. 2-93.

18. Ibid, p. 2-94.

19. Ibid, p. 2-96.

20. ONWI-19, op cit, p. 56.

TECHNICAL STRUCTURE·
NWTS PROGRAM

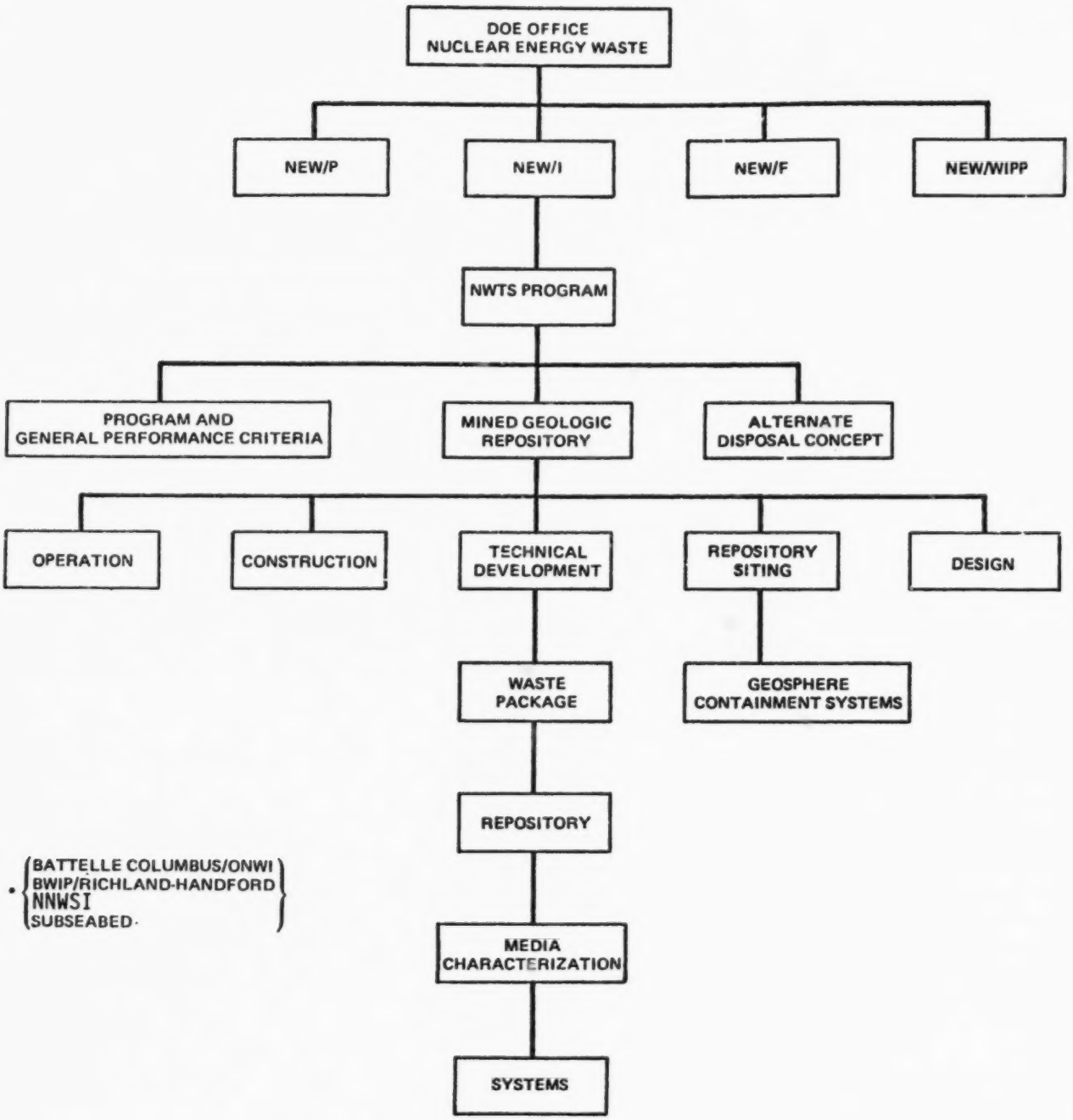

FIGURE 1

BEST DOCUMENT AVAILABLE

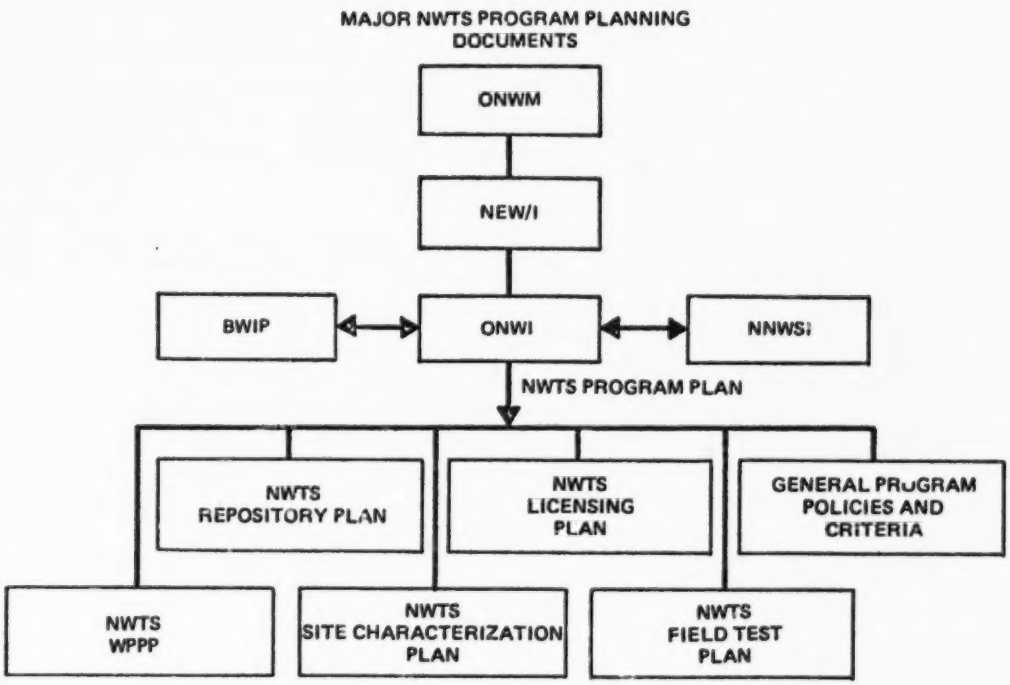

FIGURE 2a

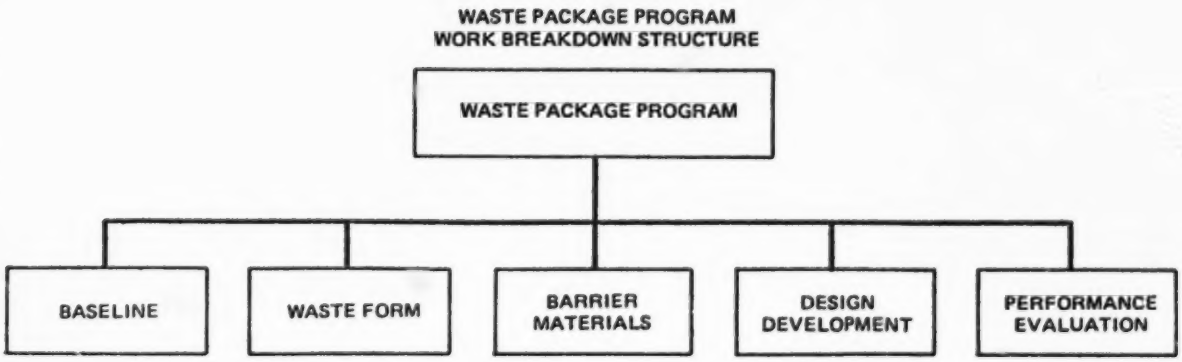

FIGURE 2b

BEST DOCUMENT AVAILABLE

ONWI ORGANIZATION

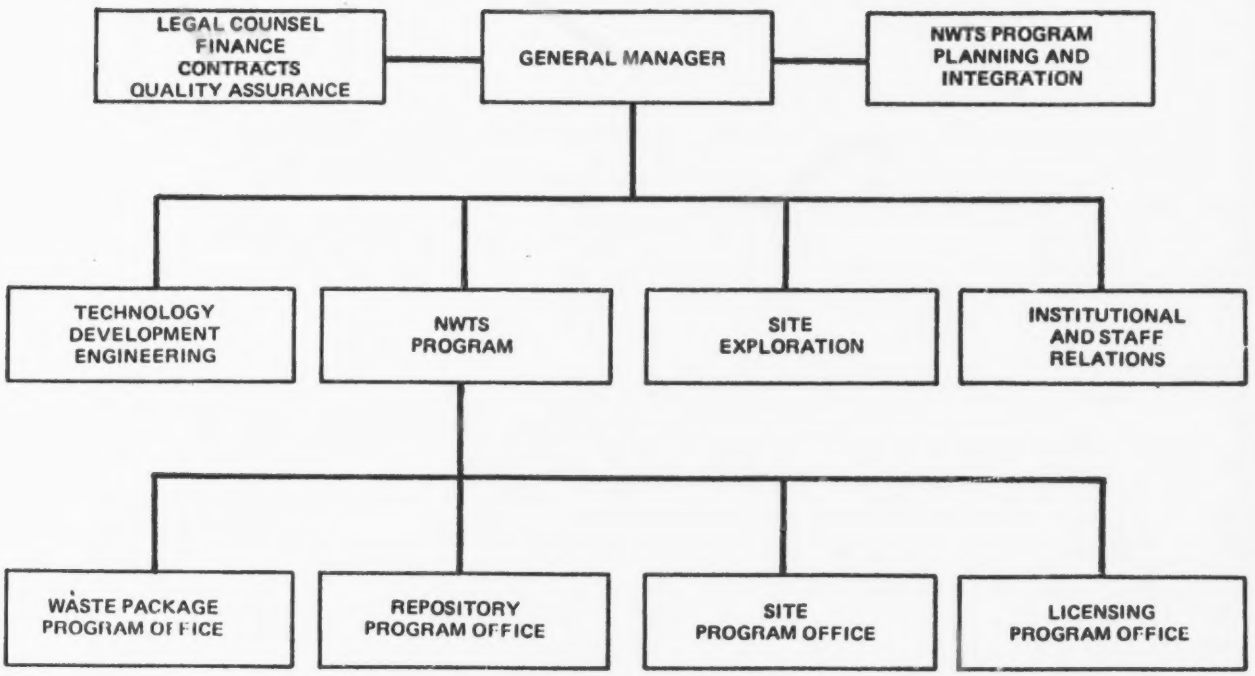

FIGURE 3

BEST DOCUMENT AVAILABLE

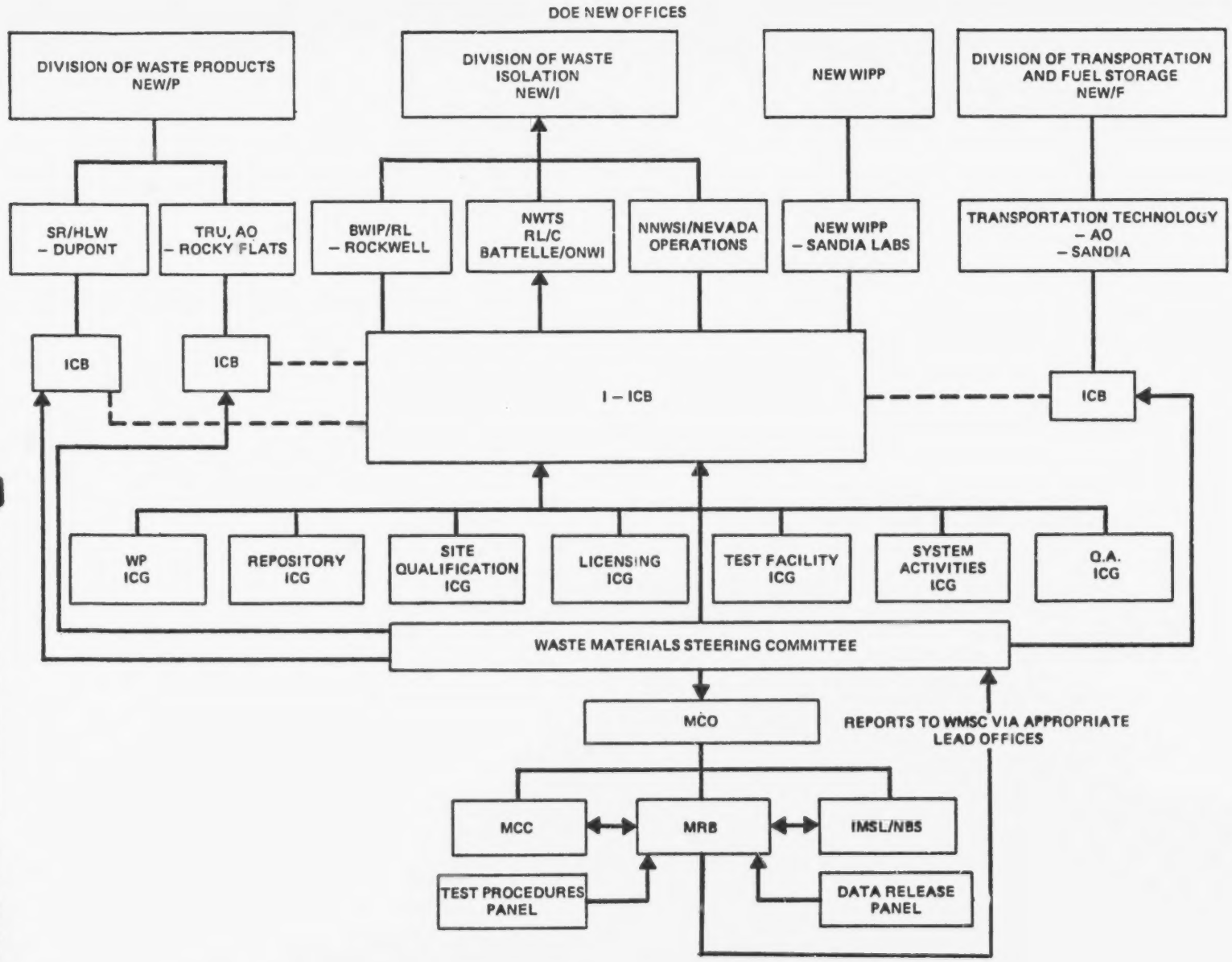

FIGURE 4

BEST DOCUMENT AVAILABLE

APPENDIX A

INTERFACE AGREEMENT BETWEEN ONWI AND SR/HLW PROGRAMS

1.0 THE WASTE PACKAGE INTERFACE

1.1 ONWI Program Charter

The Office of Nuclear Waste Isolation (ONWI) has the lead in the research, development and design of waste packages for the NWTS Program, including integrating them into repository development, design, and licensing efforts. For a given waste form, ONWI will bring the waste packages* to a ready-to-emplace stage. This includes whatever engineered barriers are to be provided, as either part of the waste package or repository, to meet specific repository and licensing requirements.

For the disposal of spent fuel from commercial power reactors, ONWI will also be responsible for the development of waste forms which can be accommodated at geologic repositories or via alternate disposal methods.

1.2 SR/HLW Program Charter

The Savannah River High-Level Waste Lead Office (SR/HLW) has the lead in the research, development, design, and manufacture of waste forms and canisters to immobilize high-level wastes from defense plants and commercial fuel reprocessors.

1.3 Basis for the ONWI - SR/HLW Program Interface

The ONWI waste package design, without major modifications, 1) should accommodate commercial HLW forms and canisters and 2) should not preclude the waste forms and canisters SR/HLW develops for immobilization of defense wastes.

1.4 Division of Responsibility

In order to implement our charter responsibility including item 1.3 above, and at the same time make best use of the funding provided, the following work division should exist between SR/HLW and ONWI.

1.4.1 Research Sponsorship

a. SR/HLW should sponsor research efforts to define and develop the waste forms for defense and commercial HLW.

---

*"Waste Package" is defined as the entire assembly of waste form, canister, overpacks, if any, or other engineered barriers that are emplaced in the geologic repository.

BEST DOCUMENT AVAILABLE

b. ONWI should sponsor research efforts to define and develop the waste forms for spent fuel.

c. ONWI should sponsor research to define, develop, and qualify the external barriers to radionuclide migration from all waste forms, including investigation of external barrier materials, components and their interaction, for natural and engineered barriers as used in licensed repositories.

d. Since there is a high probability that a canister will be the physical interface between SR/HLW (acting, for example, as shipper) and the packaging* facility, or the repository, and since canisters may also play an integral role in producing the waste form, SR/HLW should sponsor research to develop canisters that meet their production and interim storage requirements. If transportation requires a secondary container to be applied at the production facility, then SR/HLW is responsible for the R & D pertaining to this canister, coordinating the development with the Transportation and Isolation Programs.

ONWI is also interested in the canister as a potential long-life radiological barrier because of the interest in the waste package radionuclide retention being redundant to the geology in licensing safety assessments. ONWI, therefore, should sponsor research on the canister's barrier aspects. To the extent that our separate efforts on the canister can benefit both missions, they should be so organized. Canister-related projects should be closely coordinated through the interface control organization to maximize the benefits to the production, transportation and isolation programs.

1.4.2 Design Criteria and Specifications for Repository Emplacement

a. For maximum programmatic benefit, ONWI should provide SR/HLW with definitive design criteria to allow SR/HLW waste form and/or canister investigations to proceed in an orderly manner.

b. ONWI has the responsibility for developing specifications that waste forms and/or waste form-canister configurations must meet to be

*"Packaging" refers to the application of an overpack or other engineered barriers in a facility that may be located at the repository, or at a central location to service several repositories.

acceptable for repository emplacement as part of the waste package. Such development will recognize the requirement for close coordination with the SR/HLW and Transportation Programs Close coordination is essential since these specifications will significantly affect all participants. For example, the specifications might deal with leach rate, source strength, radiation flux, heat flux, dimensional limits, chemistry considerations, structural strength and weight. They might also involve qualification tests and quality assurance inspections which the waste form and/or waste form/canister configuration must pass from a safety and licensing standpoint.

1.4.3 Waste Package Program Integration

ONWI has recently established a Waste Package Development and Design Activity within the Technologies Development and Application Functional Area. The WPDD Activity will act as a focus for ONWI waste packaging research, development, testing, and design efforts, and the integration of those efforts with ONWI facility design, testing, and licensing*; and with other participants in NWTS Waste Packaging areas. A NWTS Waste Packaging Program Plan is being formulated. A Plan Framework should be available by year end.

2.0 MATERIAL CHARACTERIZATION CENTER AND MATERIALS REVIEW BOARD INTERFACES.

a. SR/HLW views the Materials Characterization Center (MCC), base-funded through the SR/HLW lead office, as essential for meeting the SR/HLW Charter.

b. ONWI sees a potentially useful role for the MCC in meeting user needs of various lead laboratories for testing and experimentation facilities. ONWI envisions users other than SR/HLW-funded groups would negotiate annual fees for work to be done at the MCC.

c. The MCC will produce the Materials Handbook. This handbook will be the authoritative reference for all NWTS waste package materials. It would serve as a data clearing house and control document for the NWTS program. It would be the authoritative data source for safety analyses to meet licensing requirements.

d. The functions of the Materials Review Board (MRB) are to 1) review and advise on MCC programs, 2) approve

*ONWI is working towards the goal that repository licensing will not extend back into a defense waste form production facility.

BEST DOCUMENT AVAILABLE

MCC test procedures, and 3) approve data for inclusion in the handbook.

3.0 INDEPENDENT MEASUREMENTS STANDARDS LABORATORY (IMSL) INTERFACE

The need for an ONWI-funded laboratory, independent of the MCC, as a quality assurance mechanism within the NEW Materials Characterization Organization has been identified. The IMSL will have authority for independent review of the activities of the MCC. The IMSL will provide an independent review of test procedures developed by the MCC or other laboratories and will develop selected test methods and procedures for Materials Review Board approval. The IMSL will also participate in the approval of the test methods and properties data published in the Materials Handbook by virtue of its membership on the Materials Review Board.

APPRCVED:

N E Carter
N. E. Carter, General Manager
Battelle Project Management Division
Office of Nuclear Waste Isolation

December 16, 1979
Date

J. L. Crandall/DHP
J. L. Crandall, Director
Advanced Planning Section
E. I. du Pont de Nemours & Company

December 3, 1979
Date

BEST DOCUMENT AVAILABLE

Organization for Materials Characterization
Office of Nuclear Waste Management (ONWM)
U.S. Department of Energy

In the nuclear waste management program, consisting of waste processing, transportation, and isolation , it is necessary to coordinate and document technical decisions that affect two or more of these activities. Coordination is essential to the development of an integrated waste disposal system and to insure that decisions made by one group are compatible with the programs of other groups. This coordination will be achieved by a formalized system of Interface Control Boards (hereafter called the Interface Boards).

This charter defines the mission, functions, and interfaces of the Interface Boards, which are an integral part of the nuclear waste management program within the Department of Energy.

I. Objective

The objective of the Interface Boards is to review and advise their respective program contractors regarding decisions reached by any one of the four activities of the waste management system (HLW, TRU, Transportation, Isolation) that interact with the programs of the other three. These decisions may involve equipment design, standards, material specifications and tests, calculational procedures, or any other aspect of the program in which two or more of the activities have a mutual interest, and therefore a mutual responsibility. Interface Boards are administrative groups that, as part of the program contractor organization, identify, coordinate, control, and document these mutual decisions.

II. Authority

The Interface Boards perform their function by authority of the Materials Steering Committee within the Department of Energy. The Interface Boards report on their activities and are responsible to the Materials Steering Committee through the appropriate lead field office.

III. Functions

The Interface Boards will define the issues, establish temporary Interface Working Groups (hereafter called Working Groups) as needed, obtain approval of the recommendations, and keep appropriate records. The function of an Interface Board is mainly administrative; the function of a Working Group is mainly technical.

BEST DOCUMENT AVAILABLE

Interface Control Board

The organizational structure of an Interface Board is as follows:

- Each lead field office will establish one Interface Board for its area of responsibility.
- Each Interface Board is a standing group.
- The size and composition is to be determined by each lead field office.
- One individual will be designated as the contact between a given Interface Board and other Interface Boards.
- The members of each Interface Board will be approved by the Materials Steering Committee

The functions of an Interface Board are as follows:

- Identify interface issues to their respective program management.
- Accept responsibility to handle the issue.
- Establish appropriate Working Groups. (Steering Committee approval not required for Working Group members).
- Accept or reject Working Group recommendations.
- Document recommendations for resolution of interface issues for transmittal through normal program management.
- Maintain appropriate records.

Interface Working Groups

The organizational structure of a Working Group is as follows:

- Structure established by lead Interface Board.
- Strong technical orientation.
- Has specific objective.
- Has finite scope.
- Has limited lifetime. Working Group is dissolved by the lead Interface Board at completion of assignment.

BEST DOCUMENT AVAILABLE

The functions of a Working Group are as follows:

- o Comprehend and accpet assignment given by lead Interface Board.
- o Resolve the specific interface issue.
- o Develop supporting documentation.
- o Make recommendation to lead Interface Board.

IV. Interfaces

The Interface Boards will support the following programs and current DOE lead offices:

High-Level Waste Program (Savannah River)
TRU Program (Albuquerque)
Waste Isolation Program (Richland-Columbus)
Transportation (Albuquerque)

Other programs and lead field offices may be added as required. The Interface Boards recommendations will be submitted through normal program management chanels.

V. Reporting

Once an issue has been resolved and approved, the lead Interface Board will distribute the documents to all other Interface Boards.

In addition to distributing reports of individual Working Groups, the Interface Boards will periodically publish a status report, identifying the issues that have been resolved, and providing a status report on each issue currently being investigated.

The reports will be numbered and identified as binding agreements among the Working Groups.

VI. Funding

Each lead field office will fund the activities of its Interface Board and its corresponding share of the Working Group expense.

BEST DOCUMENT AVAILABLE

APPENDIX B

WASTE PACKAGE ICG ACTION PLAN

WP-ICG Scope of Responsibility

The mission of the Waste Package Interface Coordination Group (WP-ICG) is to identify, delineate and evaluate waste package-related technical and programmatic issues that represent an interface with or an impact on two or more of the waste isolation programs. The Waste Package ICG shall address issues and participate in baselining (by submitting to the I-ICB recommendations for each appropriate document) of plans, criteria, reference data and specifications or other related material in the area of the waste package work breakdown structure subelements of:

(a) Waste forms
(b) Barrier materials
(c) Design and development
(d) Performance evaluation.

Additionally, in the area of the waste package, the WP-ICG will meet the general requirements of the "Generic Charter" for Waste Isolation Interface Working Groups" (May 28, 1980) and "IWG Responsibilities" documents.

Baseline Activities Planned

Baselining activity involves review and approval, and submittal to the I-ICB, of the documents providing the program planning, performance criteria, and design and performance requirements necessary to assure that the waste package task objectives will be accomplished. In FY 1981, the WP-ICG baselining activities will focus on the following documents: (1) the Waste Package Program Plan, and (2) the Waste Package Criteria document.

The schedule set for these documents is:

- Waste Package Criteria Document submitted to I-ICB for baselining — 3/13/81
- Waste Package Program Plan submitted to I-ICB for baselining — 4/3/81

Document Reviews Planned

WP-ICG reviews for other documents which will be applicable within NWTS will also be conducted in FY 81. Document reviews planned for FY 81 in this category include: (1) Interim Engineered Waste Package System Design Specification, and (2) Spent Fuel Waste Form Recommendation.

The schedule set for these documents is:

- WP-ICG review comments on Interim Engineered Waste Package System Design Specification received by WPPO — 2/10/81
- WP-ICG review comments on Spent Fuel Waste Form Recommendation received by WPPO — 9/15/81

Interface Issues To Be Addressed

Included in the interface activity are (1) ICG meetings; (2) recommendations for possible establishment of new Interface Working Groups in the waste package area to address specific technical topics; and (3) interfacing with other ICG's, for example, the Field Testing ICG, as appropriate for implementation of waste package data base needs.

The interface activity involves identification of new issues pertinent to the waste package and development of recommendations concerning these issues for submittal to the I-ICB. Two efforts within this activity which have been identified thus far are definition of waste forms for spent fuel and incorporation of TRU waste requirements into the Waste Package Program Plan. Other issues will be addressed as they arise.

Definition of the waste forms for spent fuel is of major importance, for decisions on the waste package components will depend, to a great extent, on what the package is to contain. ONWI has the assigned responsibility for defining the spent fuel waste forms for package design; this will be accomplished by July 1981, with submission of the ONWI report on this matter to the WP-ICG and DOE-NPO for review.

Integration of the TRU program within the NWTS program is very important, and is actively underway, with a draft Interface Agreement between the TRU and NWTS programs currently under review (October 1980). ONWI has the assigned responsibility for incorporating TRU waste requirements into the Waste Package Program Plan (WPPP), and will define the schedule for this issue during the second quarter of FY 81.

Overall Action Plan Schedule

The Chairman of the WP-ICG communicates with the chairmen of the other ICG's, the I-ICB and the NWTS waste package program elements on a continuing basis. WP-ICG meetings are scheduled as required. The size of the group gives the added flexibility for scheduling additional meetings or conducting business by mail at short notice if necessary to accommodate the baselining process and interface activities, or to resolve priorities and interface issues.

The schedule for the WP-ICG activities identified earlier is as follows:

- Meetings -- as required; no less frequently than annually
- Possible Establishment of New IWG's -- ongoing activity as appropriate
- Interfacing with Other ICG's -- as appropriate.

WASTE ISOLATION ICB/ICG CONCEPT

The DOE, in its role as a lead agency for the management and disposal of radioactive wastes, is conducting a number of nuclear waste programs in addition to the NWTS Program. These include efforts in waste processing, transportation, storage, decommissioning, stabilization of mill tailings, the shallow land burial of wastes, and others. The NWTS Program maintains an active and cooperative interface with these programs to ensure that the resources of all are best utilized to fulfill the needs of the total National waste management effort.

The coordination of the interfaces between the major elements of DOE's Nuclear Waste Management Program (i.e., waste processing, transportation, and isolation) is achieved by a system of Interface Control Boards (ICBs) under the technical guidance of a Waste Materials Steering Committee. Each Waste Management Program lead field office has established an ICB for its area of responsibility. The NWTS Program Office (NPO), located in Columbus, Ohio and designated by DOE HQ as the lead field office for the NWTS Program, has established the Waste Isolation ICB, referred to as the I-ICB.

The I-ICB has been established to serve two purposes. As one of the Waste Management Program ICBs, one of its purposes is to provide the mechanism to achieve interface definition and control between the various waste management programs. In this role, the I-ICB coordinates waste isolation interface activities and interactions with the other ICBs (i.e., HLW-ICB, TRU-ICB, and Transportation-ICB). When required, the I-ICB directs the participation of waste isolation program representatives on ad hoc Interface Working Groups (IWGs) formed for limited times under another ICB.* The relationships between the I-ICB, other waste management program ICBs, the ad hoc IWGs formed by those ICBs when required, the Waste Materials Steering Committee, and the overall Materials Characterization Organization, are shown by Figure 1.

The second purpose of the I-ICB is to provide interface definition and control between the various waste isolation programs, i.e., ONWI, BWIP, NNWSI, the Subseabed Program, and the Waste Isolation Pilot Plant Project (WIPP). The WIPP, although not a part of the NWTS Program, is included as one of the waste isolation programs because its objectives, issues, and technology developments parallel those of the NWTS Program. This second role of the I-ICB is achieved by standing Interface Coordination Groups (ICGs) formed to represent the various elements of the waste isolation system and program. The following ICGs have been formed:

- Systems ICG
- Waste Package ICG
- Repository ICG
- Site ICG
- Licensing ICG
- Test Facilities ICG
- Quality Assurance ICG

The I-ICB, therefore, not only fulfills the DOE waste management program interface coordination needs but, by design, fulfills the NWTS Program technical coordination and interface needs as a management body, which includes lead contractor members from the NWTS projects and the WIPP. The I-ICB is chaired

*See last page for NWTS representation on other IWGs.

by the Battelle's Office of NWTS Integration (ONI) General Manager and the ICGs are chaired by the ONI NWTS Program Office managers. The I-ICB operations responsibility is to make recommendations to the NPO on issue resolutions, issue positions, integration and control procedures/needs, and on key NWTS data documents to be controlled as part of the NWTS Baseline.

Figure 2 shows the overall relationships of the ICGs to the I-ICB and to the higher level relationships of the I-ICB to NPO, the other waste isolation program lead field offices, and the Waste Materials Steering Committee (the parent organization for Waste Management Program ICBs).

The mission of each ICG is to identify, delineate, and evaluate waste isolation technical and programmatic issues, in the particular area for which they are responsible, which represent an interface with or an impact on two or more of the waste isolation programs. Subsequently, the ICG will recommend a resolution of an interface issue to the I-ICB for approval and submittal to DOE. Collectively, all of the ICGs, working in cooperation with the I-ICB, will serve the interface coordination needs of the waste isolation programs and will help ensure that technical decisions reached by any of the NWTS projects and the WIPP are compatible with the other waste isolation programs.

The necessary interface coordination and technical/programmatic decisions addressed by the ICGs may involve design, standards, specifications, model verification, tests, procedures, criteria, plans, or any other aspect of the waste isolation programs in which the NWTS and WIPP activities have a mutual interest, and, therefore, a mutual responsibility.

The development and utilization of the waste isolation I-ICB and ICG concept represents a very effective mechanism to facilitate NWTS Program integration. While the function of the I-ICB is, primarily, administrative, the functions of the ICGs are technical and include the following:

- NWTS WBS Level 2 Baseline - Each ICG supports the definition of the Level 2 baseline in terms of data and documentation in the WBS area for which it is responsible. Subsequently, it is responsible for reviewing and approving Level 2 planning and criteria documents. ICG-approved documents are forwarded to the I-ICB for approval.

- Annual NWTS Information Meeting - ICGs support the Annual NWTS Information Meeting by coordinating the solicitation, evaluation, selection, and timely preparation of NWTS technical program papers for presentation at the meeting.

- NWTS WBS Level 2 (Task) Plan - Each ICG is responsible for coordinating the development and preparation of a TASK plan (e.g. NWTS Waste Package Program Plan) which is compatible with and supports the implementation of the overall NWTS Program Plan. With the NWTS Program Plan as guidance, each ICG initially establishes the applicability of currently identified issues, strategies and programmatic planning and reviews past, current, and planned activities within all NWTS Projects. Using these basic planning inputs, the ICG revises strategies and planning, as necessary, identifies new issues/requirements, and coordinates the development of a documented Task Plan which delineates

and schedules an organized, integrated approach to an appropriate task in the NWTS Program. The task plan will be reviewed and approved by the ICG and forwarded to the I-ICB.

- ICG Action Plan - Each ICG is responsible for preparing and submitting to the I-ICB an action plan for sequencing, prioritizing, scheduling, and implementing its individual responsibilities. These plans are routinely updated annually or as required to indicate significant changes to the I-ICB.

When appropriate, special ad hoc IWGs are authorized by the I-ICB to address specific waste isolation interface issues which are finite in nature and which can be resolved within a finite time. The ad hoc IWGs are:

- Reference Repository Conditions IWG - formed to develop and recommend generic reference repository conditions for each host rock (basalt, granite, salt, shale, and tuff) under consideration as a repository environment.

- Materials Degradation Mechanisms IWG - formed to delineate and define all aspects of long-term materials degradation mechanisms and to prepare an NWTS position relative to accelerated testing of the waste package and/or components.

* NWTS Program Representation on IWG's of other ICB's

HLW ICB - Mechanical/Physical Features Of DWPF IWG

- Technical Support To DWPF Canister EIS IWG

- High Level Waste Form Selection Factors IWG

TRW ICB - TRU Waste Package Migration Model IWG

NRC FORM 335 (7-77) U.S. NUCLEAR REGULATORY COMMISSION

BIBLIOGRAPHIC DATA SHEET

1. REPORT NUMBER (Assigned by DDC)
NUREG/CR-2333, Vol. 5
BNL-NUREG-51458

4. TITLE AND SUBTITLE (Add Volume No., if appropriate)
Nuclear Waste Management Technical Support in the Development of Nuclear Waste Form Criteria for the NRC
Task 5: National Waste Package Program

2. (Leave blank)

3. RECIPIENT'S ACCESSION NO.

7. AUTHOR(S)
M.S. Davis

5. DATE REPORT COMPLETED
MONTH: August | YEAR: 1981

9. PERFORMING ORGANIZATION NAME AND MAILING ADDRESS (Include Zip Code)
Department of Nuclear Energy
Brookhaven National Laboratory
Upton, NY 11973

DATE REPORT ISSUED
MONTH: February | YEAR: 1982

6. (Leave blank)

8. (Leave blank)

12. SPONSORING ORGANIZATION NAME AND MAILING ADDRESS (Include Zip Code)
Division of Waste Management
Office of Nuclear Material Safety and Safeguards
United States Nuclear Regulatory Commission
Washington, D.C. 20555

10. PROJECT/TASK/WORK UNIT NO.

11. CONTRACT NO.
NRC FIN A3158

13. TYPE OF REPORT
Final Report

PERIOD COVERED (Inclusive dates)
October 1979 to September 1981

15. SUPPLEMENTARY NOTES

14. (Leave blank)

16. ABSTRACT (200 words or less)

This report assesses the need for a centrally organized waste package effort and whether the present program meets those needs. It is the conclusion of the BNL staff that while the DOE has in principle organized a national effort to develop high-integrity waste packages for geologic disposal of high-level waste, the DOE effort has not yet produced data indicating that a waste package will comply with NRC's criteria. The BNL staff feels, however, that such a package is achievable either by development of high integrity components which by themselves could comply with 1,000-year containment or by the development of new waste package designs that could comply with the containment and the controlled release criteria in the 10CFR60 performance objectives.

17. KEY WORDS AND DOCUMENT ANALYSIS

17a. DESCRIPTORS

17b. IDENTIFIERS/OPEN-ENDED TERMS

18. AVAILABILITY STATEMENT
Unlimited

19. SECURITY CLASS (This report)
Unclassified

21. NO. OF PAGES

20. SECURITY CLASS (This page)
Unclassified

22. PRICE
$

NRC FORM 335 (7-77)